

INFLUENCE OF SHAPE ON THE FALL VELOCITY  
OF SEDIMENTARY PARTICLES

by

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Prepared for  
MISSOURI RIVER DIVISION  
CORPS OF ENGINEERS, U. S. ARMY  
OMAHA, NEBRASKA

through the  
COLORADO A AND M RESEARCH FOUNDATION

July 1954

MRD Sediment Series

No. 5

CORPS OF ENGINEERS SEDIMENT STUDIES PROGRAM  
FOR MISSOURI RIVER BASIN

MISSOURI RIVER DIVISION

FORT PECK DISTRICT      OMAHA DISTRICT  
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The Corps of Engineers Missouri River Basin sediment studies program was established for the development of practical sediment engineering for rational evaluation, regulation, and utilization of fluvial sediment phenomena. It was implemented as a comprehensive, basin-wide program for coordination of studies of sediment problems in the overall basin program for flood control and allied purposes as well as for continuity and perspective in the planning and design of individual projects. The program includes both investigations for the development of sediment transport theory and observations of existent and occurring phenomena for the purpose of developing the applications of theory to practical problems, developing empirical relationships, and providing aids to judgment.

The program has been conducted during the tenures of and supported by the following Division Engineers:

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Mr. G. A. Hathaway	Mr. T. H. Means
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## FOREWORD

This report summarizes a number of years of research in sediment engineering conducted in the hydraulics laboratory at Colorado Agricultural and Mechanical College. Under the direction of Dean N. A. Christensen, Eugene Serr III proposed in a Master's Thesis as a shape factor, a simple ratio of sedimentation diameter to sieve diameter. Later under the direction of Professor M. L. Albertson, Head of Fluid Mechanics Research, A. T. Corey, R. H. Wilde and E. F. Schulz conducted investigations using a shape factor proposed by Corey and natural sedimentary materials from different sources ranging in size from 1/4 mm sand to 1 inch gravel. During this same period under the direction of Professor J. S. McNown at State University of Iowa, Jamil Malaika conducted experiments in oil using steel particles with regular geometric shapes.

In 1952 a grant was made available to Colorado Agricultural and Mechanical College through its Research Foundation by the Corps of Engineers, Department of the Army, for the purpose of assembling this report and obtaining the data for the gravel particles dropped in oil. Mr. Don C. Bondurant represented the sponsor, and much credit is due him for his efforts and suggestions.

The authors are indebted to Mr. E. W. Lane of the U. S. Bureau of Reclamation for his encouragement and for supplying the initial incentive for this series of studies of shape. They are also indebted to Dr. D. F. Peterson, Head of the Department of Civil Engineering, for his encouragement and for reviewing this report.



In the interest of maximum utility, all of the available measurements and other data have been included in the Appendix. The authors hope that in this way the data will be available to others for future improvement in the techniques of sediment engineering.



### ABSTRACT

Techniques used in modern sediment engineering require knowledge of the fall velocity of sediment particles in water. Under certain conditions the fall velocity of a sphere can be computed using Stokes Law. Stokes Law, however, considers only the viscous forces on the particle. The resistance of particles falling in water is attributed to (1) viscous deformation of the fluid, and (2) inertial losses in the fluid caused by acceleration (both tangential and normal acceleration) of the fluid around the particle. The Reynolds number (a ratio of the inertial forces to the viscous forces) is a dimensionless parameter which expresses the relative importance of the inertial forces to the viscous forces in the motion of the fluid around the particle. Stokes Law is valid when the viscous forces are the predominate cause of the resistance of the particle. As Reynolds numbers become greater than 1.0 the inertial forces assume greater importance and any equation which considers only the viscous forces (such as Stokes Law) becomes less and less valid. A quartz sphere approximately 0.1 mm diameter falling in water at 20° C (68° F) would have a Reynolds number of 1.0.

To study the fall velocity of natural particles, dimensionless parameters were employed to give general solutions to the equations involved. The principal parameters employed were the Reynolds number (ratio of inertial forces to viscous forces), the drag coefficient (intensity of drag force) and the shape factor. Particles were selected at random from a number of samples of sediment having different geographical and geologic origins. The shape factor of these particles was measured.

The particles were then dropped in water and the fall velocity measured. By measuring the weight, the volume, the fall velocity and the shape of the particle, the dimensionless parameters previously listed could be computed and a graph of drag coefficient versus Reynolds number with the shape factor as a third variable could be prepared. The particles studied in this manner ranged in size from 0.25 mm to 25 mm. To verify the results from the tests on the small particles, the gravel-sized particles were also dropped in oil. Because of the viscosity difference between the water and the oil, the larger gravel-sized particles had Reynolds numbers between 1.0 and 500 when dropped in oil. It was found that the effects of surface roughness could not be ignored; therefore, data obtained from the extremely rough particles were separated from the more rounded material by plotting on separate graphs.

The data obtained by Krumbein and Malaika in tests on artificial particles were also plotted on these two graphs.

Other information regarding the extent of variation of the shape factor, relation of average shape factor to sieve size, relation of sieve size to nominal diameter and intermediate axes, relation of sieve diameter to sedimentation diameter and shape factor have also been investigated. All the available data have been assembled in the Appendix.



## Chapter I

### INTRODUCTION

The success of many irrigation and flood control projects has been seriously hampered because of man's inability to cope with the problems brought about by the presence of large quantities of sediments or other problems associated with sedimentation. Some of these might have been avoided in the design stage had present day information and knowledge been available to the designers. Other difficulties because of sediment encountered in the current operation of irrigation and river control projects might at least be alleviated, if not eliminated, by a better understanding of factors involved in the process of sedimentation.

#### Sediment Problem in Engineering

Modern sediment engineers have been greatly handicapped by the lack of physical measurements required to describe fully the forces governing the movement of sediments. Recently, theoretical methods have been developed for describing the movement of sediment and predicting the amount of sediment being transported in streams. To employ these theoretical methods, certain average hydraulic properties of the sediment and also the extent of variation of these properties from the average must be known.

#### Fall Velocity -- A Fundamental Property of Sediment

Salient among these sediment properties is the terminal fall velocity or settling velocity. Investigators have known for considerable time that the fall velocity is an important consideration in reservoir sedimentation; however, recent research has shown that the stream velocity required to move particles along a stream bed is also directly related to the fall velocity.